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Ocean Optics Protocols For Satellite Ocean Color Sensor Validation, Revision 3, Volume 2

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Chapter 12

Above-Water Radiance and Remote Sensing Reflectance Measurement and Analysis Protocols

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12.1 INTRODUCTION

As an alternative to the in-water methods of Chapters 10 and 11, water-leaving radiance can be measured from the deck of a ship. A shipboard radiometer is used to measure radiance $L_{\mathrm{sfc}}\left(\lambda,\theta,\phi\in\Omega_{\mathrm{FOV}};\theta_{\mathrm{o}}\right)$ emanating from the sea surface at zenith angle θ (usually chosen between 30^{o} and 50^{o}) and azimuth angle ϕ (usually chosen between 90^{o} and 180^{o} away the sun's azimuth ϕ_{o}). In the convention used here, azimuth angles ϕ are measured relative to the sun's azimuth, *i.e.* $\phi_{\mathrm{o}} = 0$.

The surface radiance measured with a radiometer having a solid-angle field of view (FOV) of Ω_{FOV} sr may be expressed, following Mobley (1999), as

$$L_{\mathrm{sfc}}\left(\lambda,\theta,\phi\in\Omega_{\mathrm{FOV}};\theta_{\mathrm{o}}\right)=L_{\mathrm{W}}\left(\lambda,\theta,\phi\in\Omega_{\mathrm{FOV}};\theta_{\mathrm{o}}\right)+\rho L_{\mathrm{sky}}\left(\lambda,\theta_{\mathrm{sky}},\phi_{\mathrm{sky}}\in\Omega'_{\mathrm{FOV}};\theta_{\mathrm{o}}\right). \quad (12.1)$$

$L_{\mathrm{W}}\left(\lambda,\theta,\phi\in\Omega_{\mathrm{FOV}};\theta_{\mathrm{o}}\right)$ is water-leaving radiance centered at angles (θ, ϕ) and averaged over Ω_{FOV} [as weighted by the radiometer's directional response function (see Chapter 5)]. $L_{\mathrm{sky}}\left(\lambda,\theta_{\mathrm{sky}},\phi_{\mathrm{sky}}\in\Omega'_{\mathrm{FOV}};\theta_{\mathrm{o}}\right)$ is sky radiance measured with the radiometer looking upward at angles (θ_{sky}, ϕ_{sky}). In practice, θ and θ_{sky} are numerically equal angles in the nadir and zenith directions, respectively, and the sea and sky viewing azimuths $\phi = \phi_{\mathrm{sky}}$. The reflectance factor ρ is operationally defined as the total skylight actually reflected from the wave-roughened sea surface into direction (θ,ϕ) divided by sky radiance measured with the radiometer from direction (θ_{sky},ϕ_{sky}), both quantities being averaged over Ω_{FOV} (Mobley 1999). Remote sensing reflectance is then determined, using water-leaving radiance calculated from (12.1), as

$$R_{\mathrm{RS}}\left(\lambda,\theta,\phi\in\Omega_{\mathrm{FOV}};\theta_{o}\right)=\frac{L_{\mathrm{W}}\left(\lambda,\theta,\phi\in\Omega_{\mathrm{FOV}};\theta_{\mathrm{o}}\right)}{E_{\mathrm{S}}\left(\lambda;\theta_{\mathrm{o}}\right)}, \quad (12.2)$$

where $E_{\mathrm{S}}(\lambda;\theta_{\mathrm{o}})$ is incident spectral irradiance measured above the sea surface. All of the above variables vary with solar zenith angle θ_{o}.

A simplified notation is used in Chapters 10 and 11 (and elsewhere in the protocols) when discussing water leaving radiance $L_{\mathrm{W}}(\lambda)$ and remote sensing reflectance $R_{\mathrm{RS}}(\lambda)$ derived from in-water profile measurements of $L_{\mathrm{u}}(z,\lambda)$. Because $L_{\mathrm{u}}(z,\lambda)$ is measured viewing the nadir direction, $L_{\mathrm{W}}(\lambda)$ represents radiance leaving the surface in the zenith direction (θ, ϕ) = (0^{o}, 0^{o}). Therefore, $L_{\mathrm{W}}(\lambda)$ in Chapter 11 corresponds to $L\ \left(\lambda,0,0\in\Omega\ \ ;\theta\ \right)$, and $R_{\mathrm{RS}}(\lambda)$ to $R\ \left(\lambda,0,0\in\Omega\ \ ;\theta\ \right)$, in the present notation .